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Topological analysis and visualization of interfirm collaboration networks in the electronics industry

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ABSTRACT

This study examines the topological characteristics of interfirm collaboration networks (CNs) in the global electronics industry. Our results show that high-performing firms exhibit significant relational CN power, manage CNs that follow a power-law shape degree distribution, are predominantly horizontally integrated with low geographic complexity, and maintain a balanced exploration-exploitation collaboration relationship portfolio. We complement our topological analysis with graphical visualizations of each of these CNs over three timeframes (2004-06; 2007-09; 2010-12). Theoretically, we demonstrate the association of topological CN characteristics with high-performance of firms. Methodologically, our study defines and implements a data-driven analyses and visualization of CNs in high clockspeed industries. Our study makes important managerial contributions to the systemic design, engineering, and management of CNs.

1. Introduction

Interfirm collaboration networks (CNs) are increasingly important in today's complex, global business environment [50,26]. Driven by advances in information and communication technologies [47], CNs enable participating firms to share and distribute risks [29], enhance communication and trust [59], reduce transaction costs [48], and gain access to complementary assets, skills, and knowledge [3].

Despite the economic importance, little is known about variation in the structural shape – or topology – of CNs [19]. There is a general understanding that firms must align their CNs to the market, customer, firm strategy and capabilities [13]. The "one size fits all" configuration, however, is recognized as inadequate; the ideal CN is firm-, industry- and context-specific [27,1]. This leads to the following research issues: What topological characteristics do high-performing CNs exhibit? And how do you best visualize the topological shape of CNs for sensemaking and decision support?

We pursue these questions by grounding our study in theories of complex enterprise systems, interfirm collaboration and network analysis and drawing on multiple carefully curated and integrated secondary datasets. We complement our empirical analysis with defining a methodology for developing time-based visualizations that enable us to graphically compare interfirm CN structures and provide system-level insights. In doing so, we answer the call for rigorous data-driven studies of complex socio-technical systems [46] and macroscopic investigations of complex strategic issues [2], further our understanding of the systemic design, engineering, and management of CNs, and contribute to the emerging interfirm decision support literature [22,9,7].

The remainder of this paper is organized as follows. Section 2 presents the theoretical foundation. Section 3 describes our methodology. Section 4 presents the analysis, visualizations, and a discussion of results. Section 5 concludes the paper with implications and opportunities for future research.

2. Theoretical foundation

2.1. Interfirm collaboration networks (as) systems

There has been a long-standing recognition that CNs are complex systems [37,46]. Building on Porter's linear value chain framework, [54], for instance, describes supply chains as a system whose constituent parts include material suppliers, production facilities, distribution services, and customers linked together via a feed forward flow of materials and the feedback flow of information. Today, industrial CNs are composed of a diverse set of vertical and horizontal interactions between suppliers, manufacturers, distributors, retailers, and customers, which have transformed the traditional linear value chain into a complex network of interactions between system members [31,32]. At the same time, globalization has led to geographically dispersed CNs with high levels of interfirm dependency [25]. Management of such complex networked systems requires a significant level of coordination, collaboration, delegation, and monitoring [46,13,55,36].

Traditional modeling and analysis approaches focus on individual firms or employ a dyadic lens. This approach, however, fails to account for the systemic effects resulting from the complex topological and

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behavioral aspects inherent in CNs [16]. It has been argued that effective value chain management must emphasize the importance and consideration of behavior and performance of the entire CN [45]. In particular, research has shown the value and applicability in modeling CNs as complex networked systems comprised of autonomous, self-organizing, interdependent, and adaptive members involved in the manufacturing, integration, and delivery of products and services [24,56].

2.2. Network analytic perspective

Bellamy and Basole [16] argue that there are three distinct but related research foci of prior network analytic studies of complex systems: architecture (i.e. CN structure), behavior (i.e. CN dynamics), and control (i.e. CN strategy). A network analytic perspective enables researchers to incorporate both technical and social issues and thereby offers a more holistic picture of CNs [20]. The network lens draws on the well-established field of graph theory. In the interfirm CN context, nodes tend to represent firms (or other organizational entities, such as factories) and edges represent relationships between firms, such as buyer-supplier relationships, material flow, and information exchange [14]. The resulting topology and structural properties describe the position and (inter)connectedness of firms within the CN [16].

It has been argued that real-world CNs assume one of three common network topologies (random, small-world and scale-free), each having strengths and weaknesses [42], and differing impact on performance, dynamics, and governance (e.g. [42,38]). Basole et al. [12], for example, empirically show using a network analytic lens that centrally positioned firms tend to accrue substantial benefits, helping them reduce transactional costs and improve operational efficiency, ultimately leading to better operating and business performance. Correspondingly, studies have shown that the type and nature of CN relationships matter as well. For instance, researchers identified that the strength of a CN relationship – assessed in terms such as frequency, age, or intensity – can positively facilitate knowledge exchange [61] and new product development outcomes [41].

2.3. Collaboration

CNs are characterized by two or more participating firms agreeing to invest resources, share information, resources, rewards, and responsibilities, as well as often make decisions and solve problems jointly [50]. Collaboration thus involves some cooperative behavior. There are plentiful motivations for firms to collaborate, including capturing increased economies of scale, operational cost-effectiveness and efficiency in todays global markets, access to resources, core competencies, and innovative skills, better financial performance, and greater innovation [52,28].

Two well-established theoretical lenses explain these motivations. First, the transaction cost economics (TCE) perspective suggests that firms will establish collaborative relationships when the costs incurred for particular activities is perceived to be lower than when performed within existing organizational boundaries [60]. [33], for instance, examined the motivation of a firms knowledge transfer behavior from a TCE perspective and found that firms will engage in relationships when knowledge transfers are more efficient than market means. TCE has proven particularly applicable in explaining the shift towards vertical integration, which has been shown to occur in interfirm contexts where there is a high frequency of interaction and a great deal of asset specificity [60]. A second perspective is the resource based view (RBV) of the firm [5]. The RBV suggests that firms pursue collaborative relationships not necessarily to reduce transaction costs, but because higher levels of integration of resources, assets and capabilities is often difficult to imitate and can thus lead to greater growth and performance of the firm [33].

Collaboration is particularly prevalent in high-growth, technology-intensive industries where technology and knowledge necessary for sustained innovation often lie outside a firms traditional core competence [23]. Through a series of case studies, [53] found that CNs not only enabled firms to integrate and link operations for increased effectiveness but also enabled radical and incremental innovation. Collaboration allows sharing of knowledge and enhances knowledge creation and innovation spillovers from the supplier [30]. Collaboration in the supply chain also enhances innovation as evidenced in various logistics activities such as new product development, process improvements, service delivery, inventory management, technology transfer and capacity planning [30,53]. These findings are corroborated by [52] in an empirical study that found that CN members who had higher levels of collaboration achieved better operational performance and innovation activities.

The organizational learning literature also distinguishes collaborative relationships in terms of their motivation to either exploit existing capabilities or to explore new opportunities [35]. Exploitation places emphasis on the development of existing products, processes, or resources with incremental improvements, efficiency and risk reduction as primary objectives. Exploration on the other hand typically relates to the exploration of knowledge as well as the search and discovery of innovation, with radical improvements, experimentation and risk-taking as central objectives.

3. Methodology

3.1. Data

Our study utilizes multiple data sources to create the topology of CNs in the global electronics industry. We focus on the electronics industry for several reasons. First, prior work has shown that the electronics industry is characterized by high levels of collaboration and partnering [51]. Second, the electronics industry operates under a high clock-speed, with new products and services emerging rapidly. New forms of supply chain IT solutions and practices are thus more likely to be adopted. Lastly, the electronics industry is arguably one of the most global with the majority of firms coming from Asia, Europe, and North America, enabling us to capture the geographic footprint of CNs.

In order to understand the state of practice, we limit our study on the CN structure of high-performing supply chain firms. We identify relevant focal firms using the Gartner Top 25 Supply Chain list.[1] This list, first launched by AMR Research in 2005, identifies global supply chain leaders drawn from the Fortune Global 500 and Forbes Global 2000 rankings.[2] The list is widely used in the supply chain management and strategy literature (e.g. [21]). An examination of the annual rankings from 2007-2012, shown in Table 1, reveals 12 well-known, highly reputable and very innovative electronics companies. We chose 2007 as the starting year of our study as it marked the era of transformative change in the electronics industry with the emergence of the smartphone.

The CN structure for each of these companies was then built using two data sources: Thomson Reuters SDC Platinum Alliance & Joint-Venture database (from hereon SDC) and Connexiti. SDC is a commonly used data source for the study of strategic alliances and industry networks and is regarded as one of the most comprehensive databases of its kind [49]. SDC includes information on many different types of collaborative relationships, including strategic alliances, supply, research and development (R&D), marketing, licensing and manufacturing. We include all active relationships between 2004 and 2012 in which at least one of the companies described below has participated. We

[1] www.gartner.com/technology/supply-chain/top25.jsp

[2] Supply chain leaders are determined by an assessment of three weighted components: financial performance (50%), analyst opinion (25%) and peer opinion by supply chain professionals (25%). Financial data is taken from each firm's annual report.